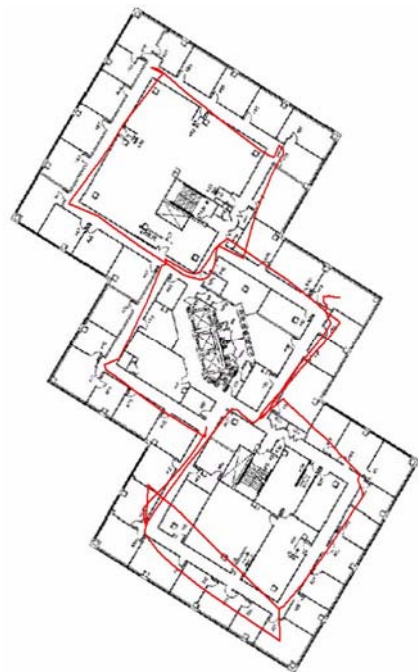# Fire Fighter Tracking and Locating Systems

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Information Technology Laboratory

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Gaithersburg, MD 20899

NIST

National Institute of Standards and Technology

Technology Administration, U.S. Department of Commerce

Overview

- **Introduction**
  - Locate who, where, and under what conditions

- **Locating/Tracking Technology**
  - Wireless Sensors
    - Building
    - Fire fighter
  - Pedometry
  - Networks
   - Fixed
    - Ad-Hoc

- **Summary**

Why Invest in Locating/Tracking Technology ?

- Firefighter Fatalities –
  - 117 in 2004 (USFA)
- Total Injuries –
  - 80,800 in 2004 (NFPA)
  - Fireground – 37,976 injuries

Pie chart:
- Fireground 47%
- Responding/Returning 7%
- Other On-duty 18%
- Training 9%
- Non-fire Emergency 19%

- Magnitude of U.S. Annual Losses ~ $128 billion total cost

- Tracking fire fighters allow
  - Better tactical decisions
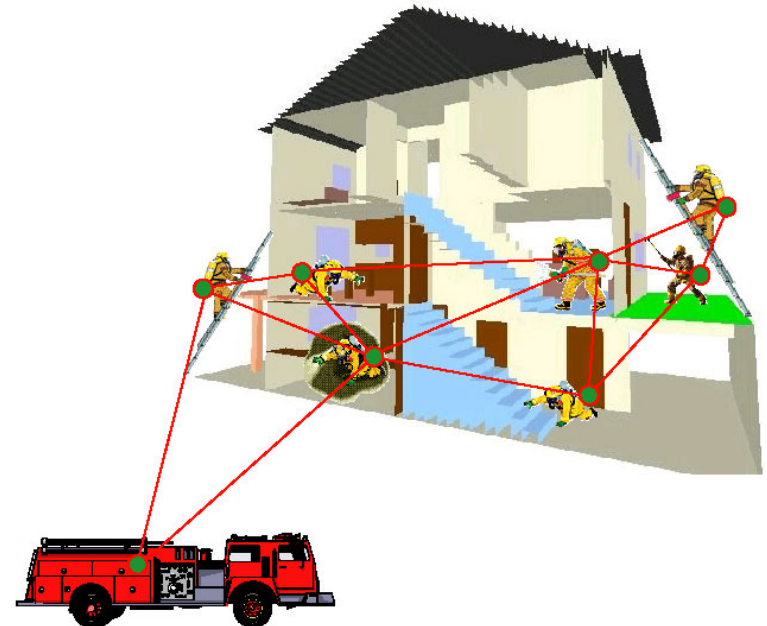   - Faster suppression
    - Decreased property losses
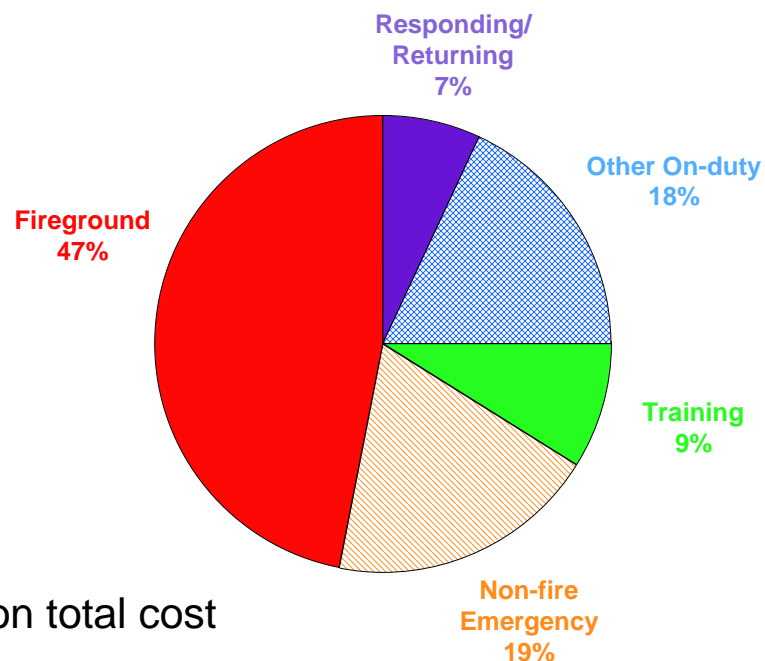
Location Data – Who ?

– Who is being located or tracked?
  - First responders
    – Fire fighters
    – Law enforcement
  - Building occupants

– Who uses the locating/tracking data
  - First responders
  - Incident commander
  - Rapid intervention team
  - Rehab team

Locating versus Tracking

- Locating
  - Determining the current location

  - Rescue/Extraction
  - Send additional equipment/support

- Tracking
  - Determining current location, movement, & history

  - Rescue/Extraction
  - Send additional equipment/support

  - Tactical decision
    - Fire suppression
    - Apprehension
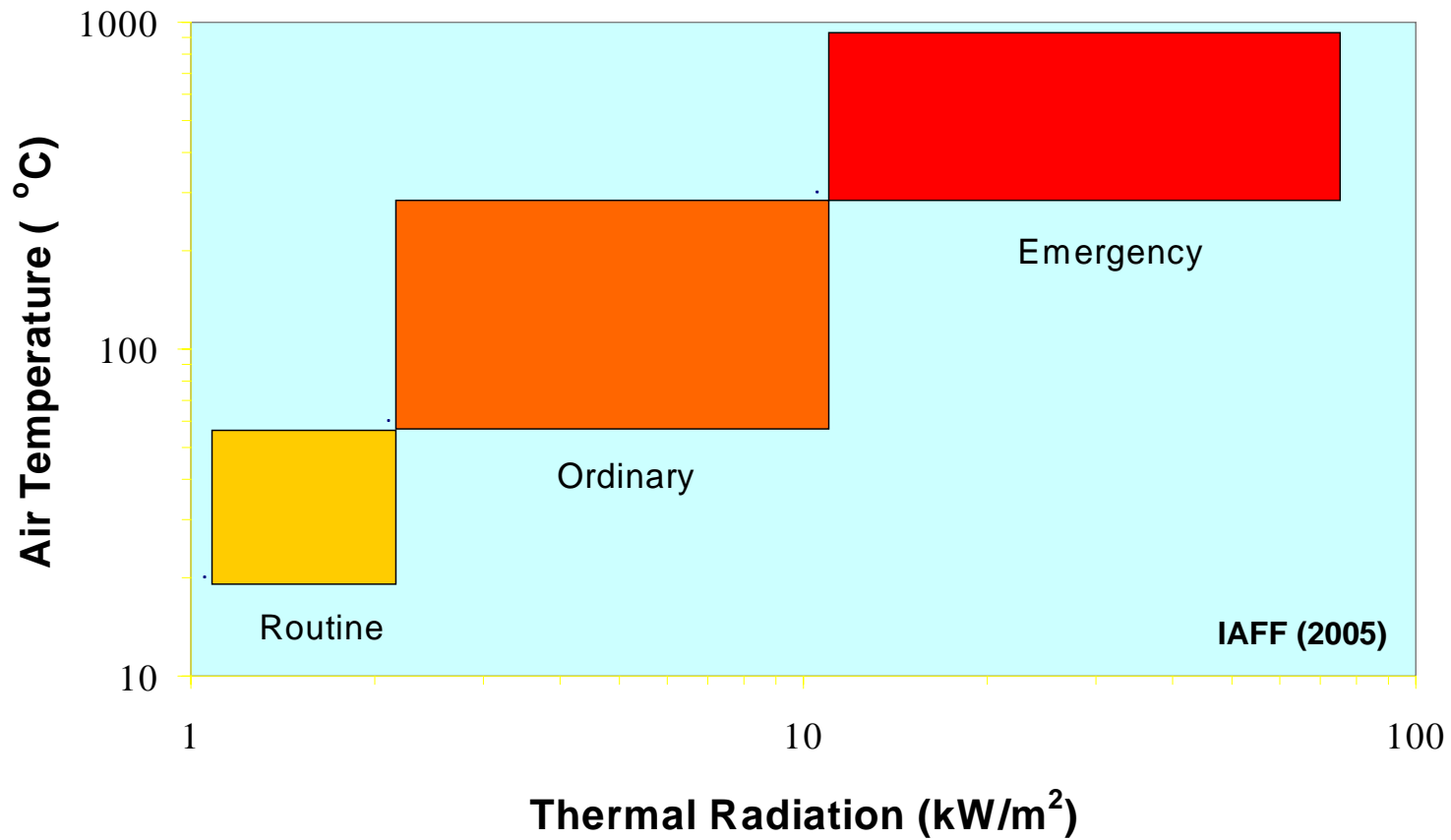
Where or what building type ?

- Type I or Fire-Resistive (NFPA)
    - High rise office, shopping centers, or residential units
    - Reinforced concrete, structural steel (protected)
- Type II or Noncombustible
    - Office buildings, warehouses, auto repair shops
    - Metal frame with metal walls, metal frame with masonry walls, masonry walls with metal roof
- Type III or Ordinary
    - Office buildings, retail stores, mixed occupancy, apartment buildings
    - Noncombustible bearing walls and combustible roofs
    - Most buildings are of this type
- Type IV or Heavy Timber
    - Exterior noncombustible or limited combustible, masonry
    - Interior structural members, walls, columns, floors and roofs are large timbers
    - Common in the New England area
- Type V or Wood Frame
    - Single family dwelling, restaurants, retail stores
    - Log, post & beam, ballon, platform, and plank & beam
    - Structural members are wood and exterior walls are combustible

Under what conditions ?

Chart: Air Temperature (°C) vs Thermal Radiation (kW/m²)

- Routine
- Ordinary
- Emergency

IAFF (2005)

Locating/Tracking Technology

- **Roles of NIST**
  - Fundamental Science
    - Measurement or metrology
    - Signal penetration
    - Sensor design
    - Combustion Science

  - Building performance
  - Fire Environment

  - Performance Standards and Testing Protocols
    - Signal quality
    - Sensor interfaces/performance
    - Thermal exposure testing
    - Network design

  - Develop new technology where expertise exists

Locating/Tracking Technology

- **Wide range of technologies**
  - Tags and peg boards
  - Chalkboards
  - Acoustic/sound
  - Radio frequency
  - Infrared signal

- **Source of Technologies**
  - Military
  - Security and surveillance industry
  - Health Care
  - Robotics
  - Fire Service Equipment
    - Limited due to the market size/funding

Wuireless Building Sensors

- **Building Sensors**
  - **In place to track building performance**
    - **Attached to specific equipment**
    - **Designed for months/years of service**
  - **Locate and track**
    - **Sample frequency**
      - Buildings – samples / hours
      - Fire fighters – samples / second

- **Issues –**
  - **Need complete building coverage**
    - **Not just equipment spaces**
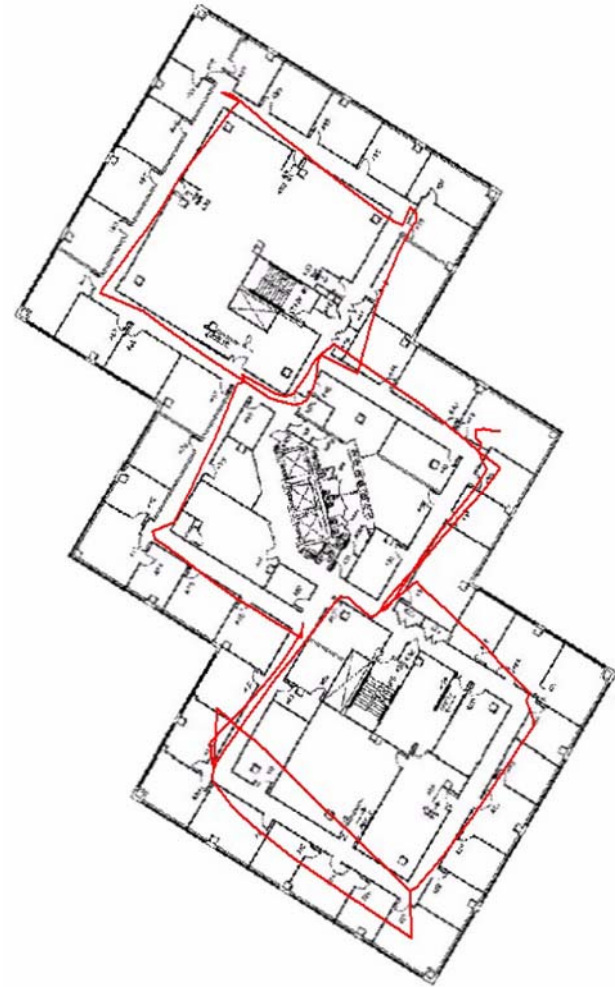 - **Require pre-wiring of building**
  - **Adaptive sampling?**

Wireless Fire Fighter Sensors

- **Component mounted on or used by fire fighter**

- Transmitter/receiver system
    - Acoustic/sound signal
    - Radio signal
    - Infrared signal

- Locates fire fighter
- Tracks fire fighter

Acoustic Systems

- Transmitter/receiver system
  - Acoustic or sound waves
- Locates fire fighter
- Commercially available
  - Summit Safety

- Issues-
  - No tracking
  - Reflections –
    - Must compare strength of signal
    - Materials reflect differently
    - Multiple reflections

•**Radio Frequency Based Systems**

   •**VHF – 30 MHz to 300 MHz**

   •**UHF- 300 MHz to 3 GHz**

   •**UWB – pulse "riding" on RF carrier**

      2.4 GHz – 5.4 GHz

•**Triangulation**

   •**Multiple transmitters/receivers**

•**Time of flight**

   •**Single transmitter/receiver**
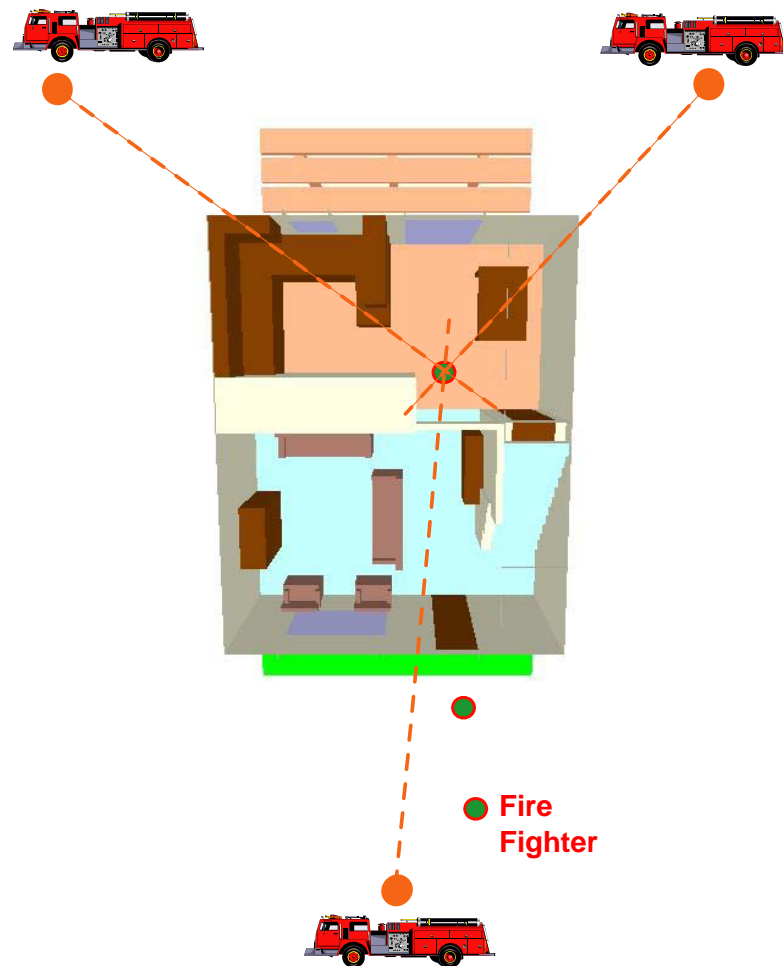
•**RFID Tags**

   •**Reader / tag**
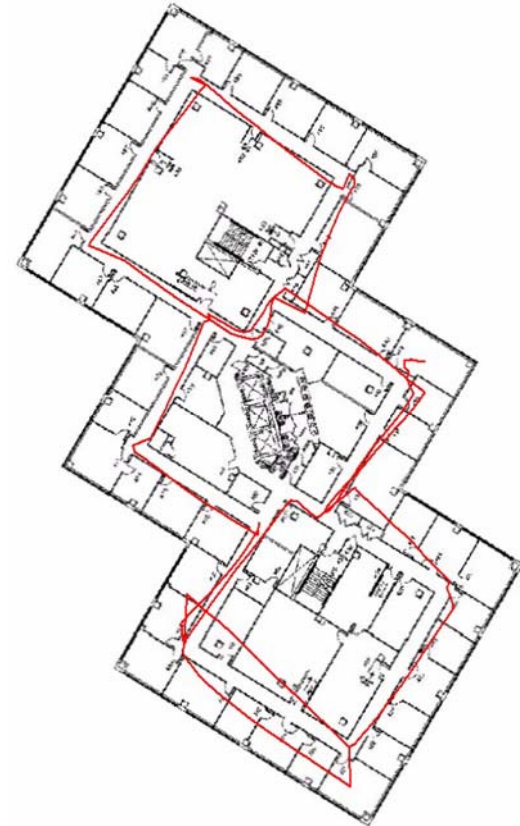
•Triangulation

- •Front and rear of structure
- •Intersection of signals identifies position
- •Can provide elevation

•Issues-

- •Signal penetration/attenuation
- •Reflections
- •Requires at least 3 units

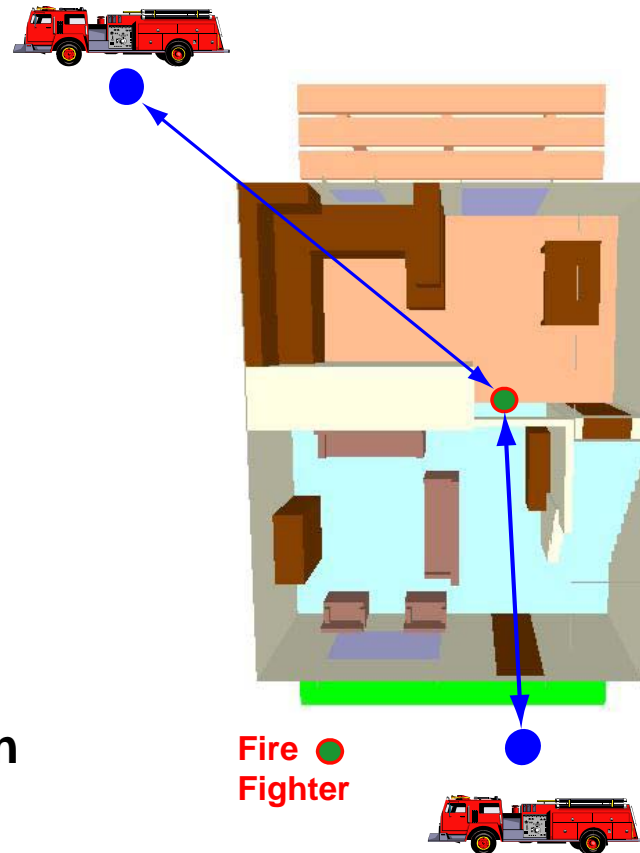Fire Fighter

- **Time of flight (TOF)**
  - **Single transmitter/receiver**
  - **Track time for signal to travel between units**
  - **Can provide elevation**

- **Material properties known**
  - **Model attenuation**
    (Lytle & Stone NIST)

- **Issues**
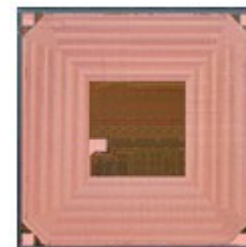 - **Signal penetration/attenuation**
  - **Reflections**

Fire Fighter

•**RF Identification Tags**

•**Reader and Tag uniquely identified**

•**RFID readers in building**
  •Each fire fighter is tagged
  •Walmart tracking merchandise
       in warehouse
  •Nursing homes – patients

•**RFID tabs in building**
  •Each fire fighter has reader
  •Readers more expensive

RFID Tags cont'd

•**Issues-**

   •**Pre-wiring of readers/tags**

   •**Signal**
      •**Coverage**
      •**Penetration/attenuation**
      •**reflections**

Pedometry

- **Distance**
  - **Count steps – assume distance/step**
- **Direction**
  - **Compass**
  - **Gyros**

- **Issues-**
  - **Errors are integrated**
    - **Distance**
      - **Different stride**
      - **Climbing stairs/ladders**
    - **Direction**
      - **Sudden movement/fall**
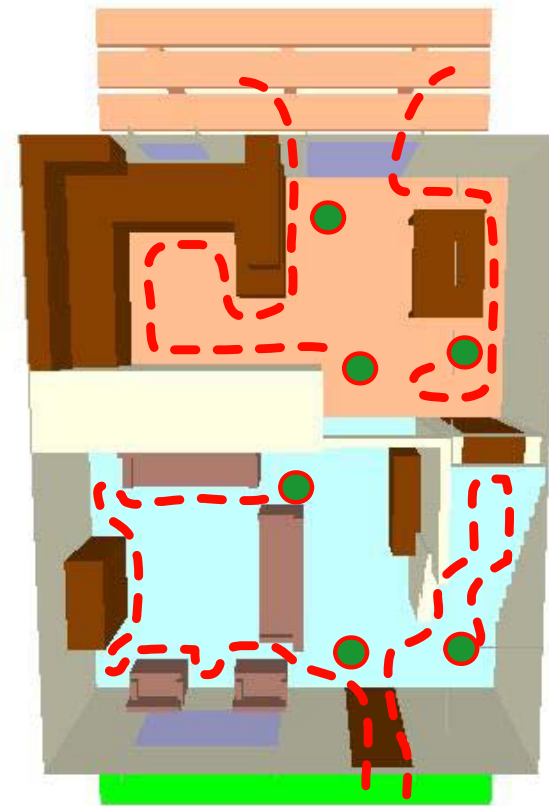
Fire Fighter ●

Red = Pedometry
Green = GPS

Pedometry Corrected

- **GPS – update location**
  - **Fire Fighters**
    - **Carnegie Mellon University**

- **RFID Tags**
  - **Reference Tags – encoded with location data**
  - **Peformance**
    - **Separation of reader & tag**
    - **Number/coverage of tags**
    - **High temperature exposure**
  - **Advanced Network Technology Division (NIST)**
  - **Fire Research Division (NIST)**
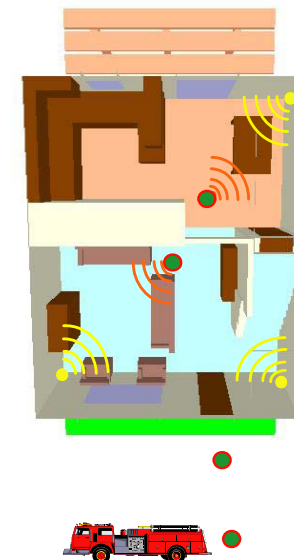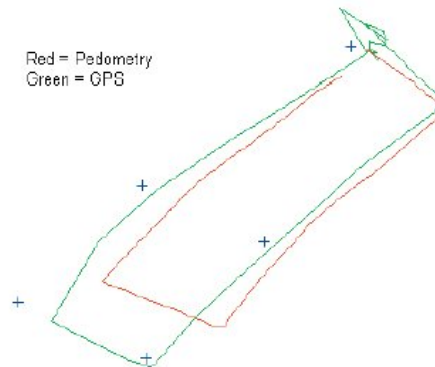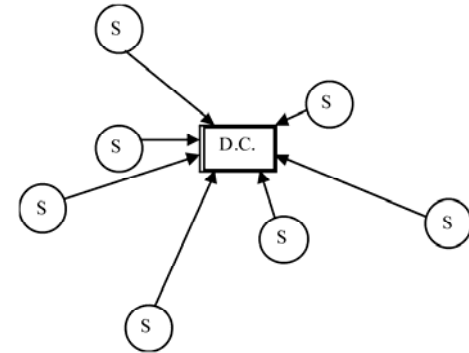
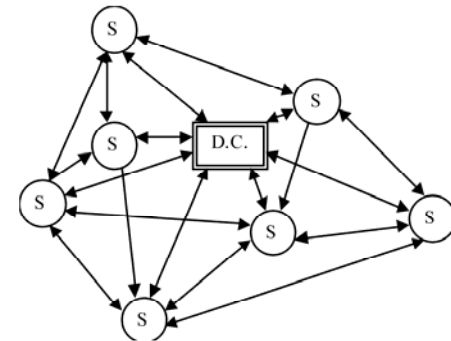# **Wireless Fire Fighter Sensors** cont'd

Sensor Networks

- **Fixed**
  - **Pre configured**
  - **Data paths established**

- **Ad Hoc**
  - **Self healing or reforming**

- **RF systems**
  - **802.15.4 ZigBee**
  - **Bluetooth**

Star or Point-to-Point

Mesh Network

- **Fixed networks**
  - **Multi-hop**
  - **Voice/data communication**
    - **Williams-Pyro (SBIR)**
  - **Not locating/tracking**
    - **Strength of signal**
    - **TOF**
- **Issues-**
  - **Limited ability to dynamically add new nodes/sensors**
  - **Short range**
  - **Node drop-out**

Building #1   Building #2

ICU

LEGEND
- **DART**: Distributed Automatic Reconfigurable Transponder
- **ICU**: Incident Command Unit
- **SN**: Sensor Node
- Wireless Link
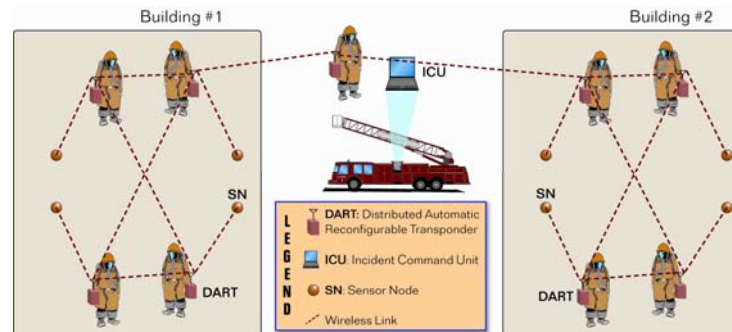
Wireless Fire Fighter Sensors cont'd

- **Ad Hoc Networks**
  - **Self-forming/re-forming**
  - **Data communication**
    - **Locating and tracking**
      - **GPS**
    - **Physiology sensors and dosimeters**
    - **Siemens (USAF)**

- **Dynamically add sensors/nodes**
  - **Data paths established on the fly**
  - **Repetitive pinging to locate nearby nodes**

- **Issues-**
  - **Short range**
  - **Path determination**
    - **Ping, ping, ping, ping, ping, ping**
  - **Data, but not voice**
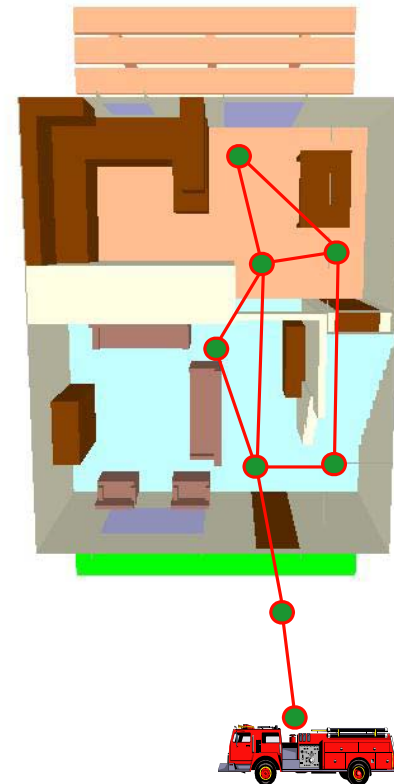
Locating/Tracking Summary

- **Locator/Tracker**
  - Interior of Structure
    - Commercial systems for indoor use
    - Pre-wired for limited coverage
  - Outside of Structure
    - GPS based systems

- **Locator**
  - Interior of Structure
    - Downed fire fighter

- **Currently no commercially available system**
  - Locate and track
  - Inside and outside
  - Fire responders
  - Occupants

Locating/Tracking Future Work

- **Assist in development of new technology**
  - **Technical expertise**
  - **Internal research funds**
  - **Grants**

- **Evaluate current systems**
  - **Laboratory-scale tests**
  - **Full-scale fire exposure tests**
  - **Collaborate with Fire Service**

- **Standards & testing protocols**
  - **Representative building types**
  - **Representative exposure conditions**

Objective-

- To provide a forum for the presentation and discussion of fire research projects that impact first responders,

  - fire fighting technology,
  - fire and building codes/standards,
  - fire-resistant materials, and
  - fundamental combustion science.

NIST Annual Fire Conference 2006

9:00- 12:30 Fire Fighting Technology/Egress

9:00   **Introduction**

9:05   **Personal Protective Technology for First Responders**
                  - R. Shaffer (NIOSH NPPTL)

9:30   **Research Agenda for Fire Fighter Life Safety**
                  - J. G. Routley (NFFF)

9:55   **Break / Poster Viewing**

10:25   **Computer Modeling of Respiratory Protection**
                  - K. Butler (BFRL)

10:50   **Fire Fighter Tracking and Locating Systems**
                  - N. Bryner (BFRL)

11:15   **Protective Clothing from Nanotube Based Fabrics**
                  - J. Gilman (BFRL)

11:35   **Virtual Fire Fighter Trainer**
                  - G. Forney (BFRL)

12:00   **Egress Data and Modeling**
                  - J. Averill (BFRL)

Under what conditions ?

Thermal Class	Maximum Time (min)	Maximum Temperature (°C)/(°F)	Maximum Flux (kW/m^2)
I	25	100/212	1
II	15	160/320	2
III	5	260/500	10
IV	<1	>260/500	>10